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U1S S1032 S2159

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US 4018534 A

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UK CL (Edition J) G1A ABA ACD ADJ ADM
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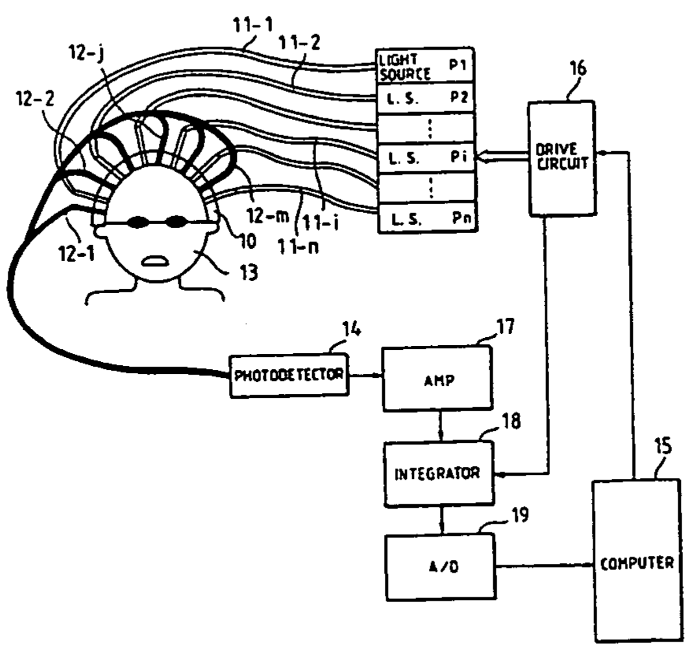
WPI/L ONLINE

(54) Optical examination apparatus

(57) Apparatus for examining an object 13 of interest by transmission photometry comprises a plurality of sequentially activated light sources P_1 - P_n arranged to direct into the object at respective incidence sites via optical fibres 11. Light transmitted into and scattered within the object is detected at a plurality of output sites on the object, the signals from the sites being combined so as to determine optical absorption data at the incidence site then being addressed. As shown the light from the output sites is combined in a fibre optic arrangement 12 and incident on a common detector 14, but each output site could have a respective detector, the signals therefrom then being added. Light of different wavelengths may be used e.g. to monitor oxygen/glucose in the brain.

FIG. 1



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy

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FIG. 1

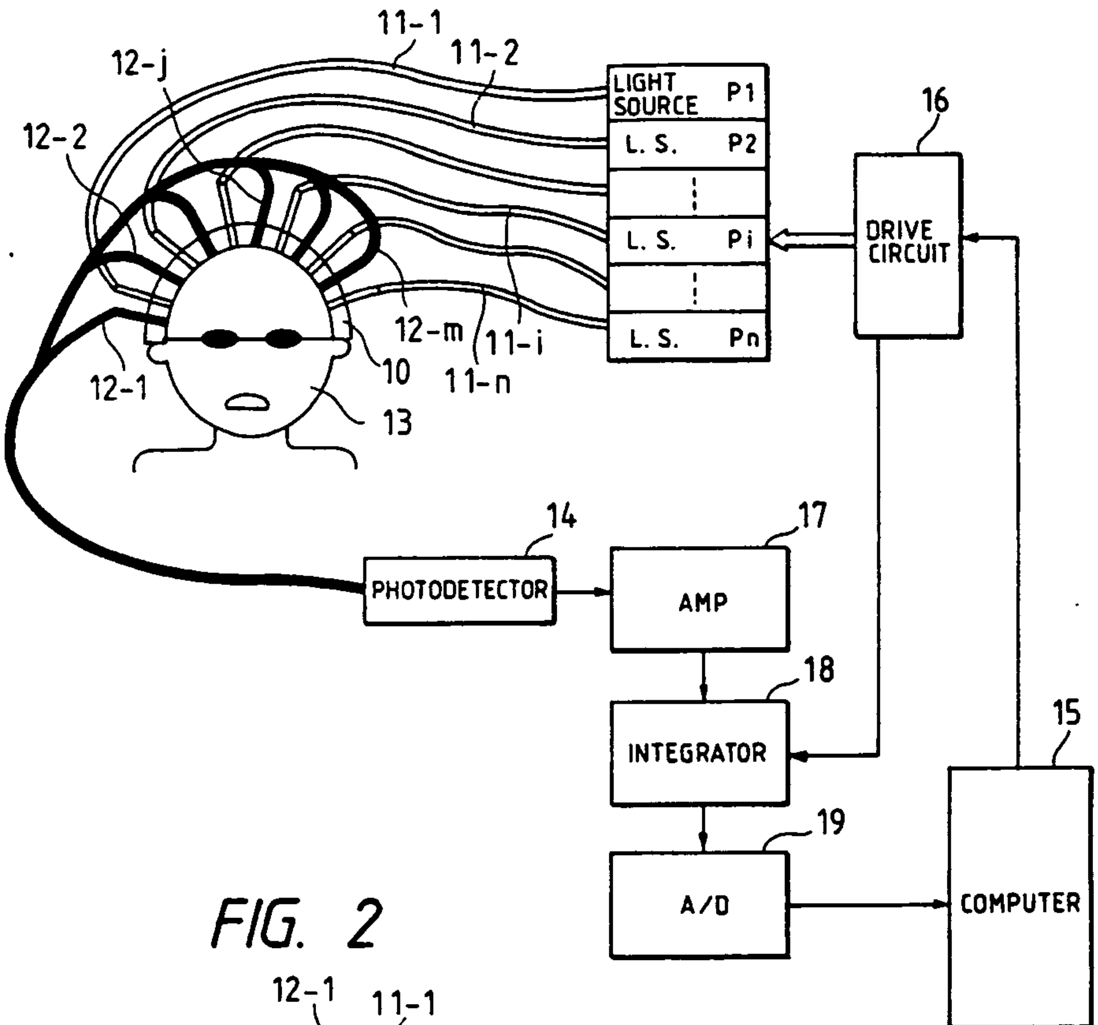

11-1
11-2
12-j
12-2
LIGHT SOURCE P1
L. S. P2
L. S. Pi
L. S. Pn
16
DRIVE CIRCUIT
12-m
11-i
12-1
10
11-n
13
14
17
PHOTODETECTOR
AMP
18
INTEGRATOR
15
19
A/D
COMPUTER

FIG. 2

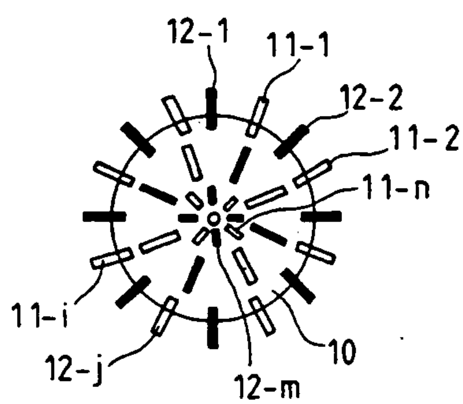

12-1
11-1
12-2
11-2
11-n
11-i
12-j
12-m
10

FIG. 3

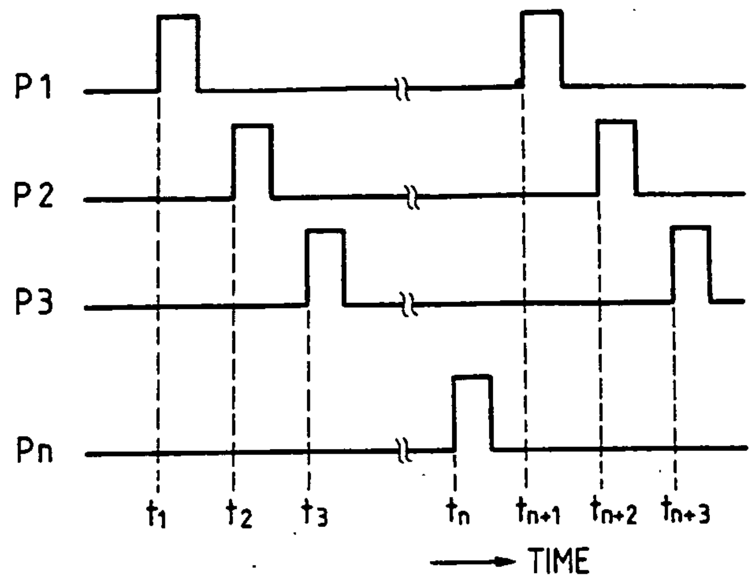


FIG. 4

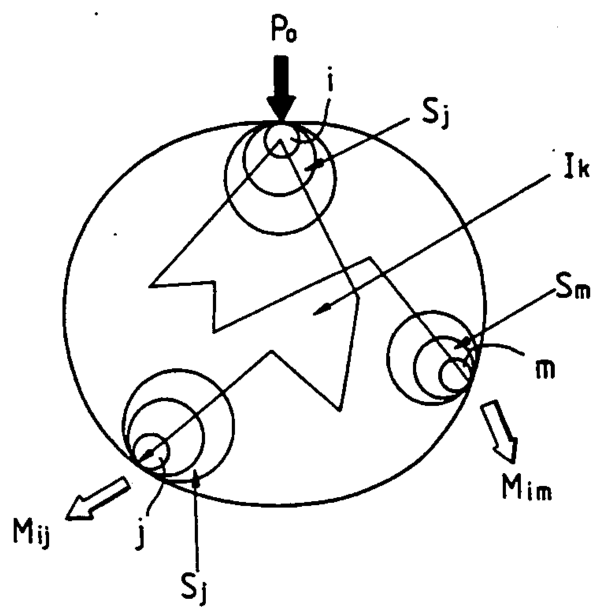
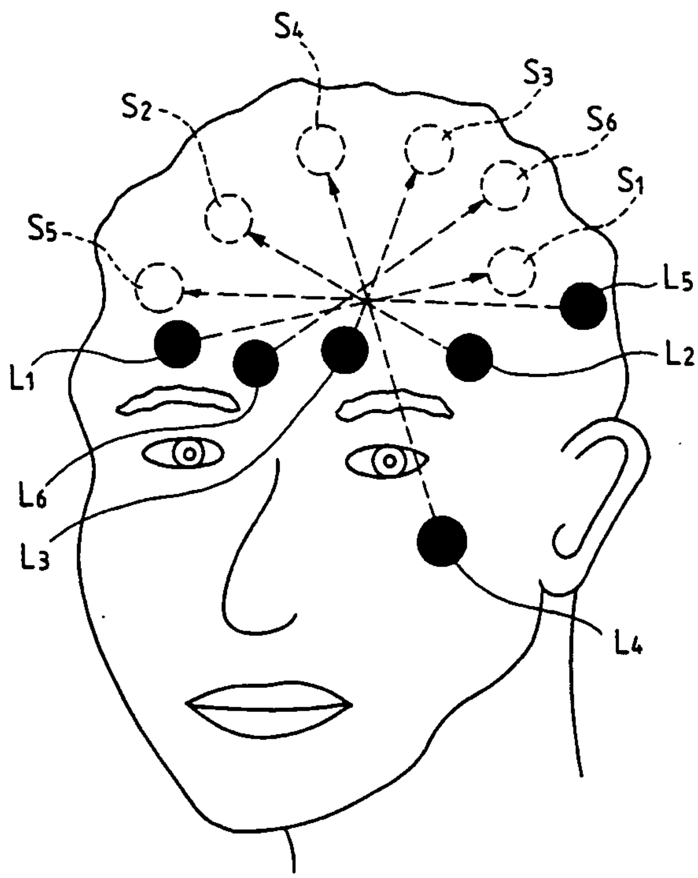


FIG. 5 PRIOR ART



EXAMINATION APPARATUS

The present invention relates to an apparatus for examining an object by detecting light transmitted through the object. Such apparatus may be used, for example, for diagnostic examination of the brain.

Apparatus is known which facilitates diagnosis of various body organs such as the brain by making use of light. Figure 5 illustrates the prior art examination apparatus disclosed in US-A-4,281,645. As shown, a plurality of light launching fibres L_1 - L_6 for guiding light beams emitted from the corresponding number of light sources and a plurality of light pickup fibres S_1 - S_6 that are associated with the fibres L_1 - L_6 are attached to the head. The pickup fibres S_1 - S_6 are located on positions that are opposite to those of the associated launching fibres L_1 - L_6 in such a way that near infrared light beams launched into the head through fibres L_1 - L_6 will be guided to a photodetector for detecting the quantity of light that has been transmitted through the head.

In the apparatus shown in Figure 5, near infrared light beams are sequentially launched from fibres L_1 - L_6, and the quantities of light that are transmitted through the head and emerge from the pickup fibres S_1 - S_6 that are associated with the fibres L_1 - L_6 are sequentially detected with the photodetector. On the basis of the quantities of transmission light that have been guided by the pickup fibres S_1 - S_6 and detected by the photodetector, the absorption of near infrared light by hemoglobin in the brain is calculated to determine the temporal or time-dependent change in cerebral blood flow and the oxygen saturation in blood. This enables the

measurement of light absorption at various sites in the brain on the straight lines that connect the launching fibres L_1 - L_6 and the pickup fibres S_1 - S_6.

As described above, the light launching fibres L_1 - L_6 in the prior art examination apparatus correspond in a one-to-one relationship to the light pickup fibres S_1 - S_6. Therefore, in order to achieve high-sensitivity detection of the light absorbence at sites in the brain on the straight line that connects a certain launching fibre, say, L_1 and the corresponding pickup fibre, say, S_1, the light emitted from the light source connected to the launching fibre L_1 has to be of correspondingly high intensity. As a further problem, the prior art apparatus is not suitable for precise detection because a slight shift in the directions or positions of the fibres L_1 and S_1 causes a great variation in the light detected. There is also a further problem that in the brain the direction of light travel is considerably disturbed by scattering.

According to the present invention an examination apparatus for examining an object with transmission photometry, comprises:

a light output device arranged to direct a light beam into the object at an incidence site; and

light pickup means arranged to receive light transmitted through and scattered in the object at a plurality of different output sites and to operate in synchronism with the light source to combine signals from the different output sites to determine light absorption data for the incidence site.

The present invention provides an examination apparatus which determines the absorption of light at an incidence site with high sensitivity but does not require a high intensity light source. By detecting light injected at a single incidence site at a number of different output sites the apparatus is able to recover

indirectly scattered light as well directly transmitted light. Moreover the present inventor has found that by combining light from different output sites absorption in the bulk of the body and at the output sites is effectively averaged out, giving an output dependent on local absorption of the incidence site. This output is largely insensitive to shifts in the position or direction in which optical fibres are attached to the object to be measured.

Preferably the light pickup means is arranged to combine signals from the different output sites additively. Preferably the light pickup means include a photodetector arranged to receive light from the output sites and to produce an output dependent on the total intensity of the light from the output sites.

Preferably the detector further comprises an integrator arranged to integrate the output of the photodetector with respect to time.

Preferably the light pickup means includes a plurality of photodetectors for detecting light at respective output sites and producing a signal proportional to the intensity of that light and computing means for adding signals from the plurality of photodetectors.

Preferably the apparatus includes a plurality of light output devices, arranged to direct light into the object cyclically at a corresponding plurality of incidence sites; and the light pickup means is arranged in synchronism with the injection of light at successive incidence sites to combine the signals from the plurality of different output sites, making successive determinations of light absorption data for respective incidence sites.

An example of an examination apparatus in accordance with the present invention will now be described and contrasted with the prior art with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram showing the constitution of an examination apparatus according to an embodiment of the present invention;

Figure 2 is a plan view of a cap in helmet form;

Figure 3 is a timing chart for the driving of a plurality of light sources;

Figure 4 is a diagram showing the light path launched into the head; and

Figure 5 is a diagram showing an application of a prior art examination apparatus.

Figure 1 is a schematic diagram of an examination apparatus according to one embodiment of the present invention. Figure 2 is a plan view of a cap in helmet form. As shown in Figures 1 and 2, a helmet-like cap 10 has a plurality of light launching fibres 11-1 to 11-n and a plurality of light pickup fibres 12-1 and 12-m that are attached to the cap in such a way that they surround uniformly an object to be measured, say a head 13. These fibres are attached in such a way that their tips are located either in contact with the head 13 or in its vicinity when the cap 10 is put on the head 13.

The launching fibres 11-1 to 11-n are connected at the other ends to associated pulse light sources, such as laser diodes, P1 to Pn. The pickup fibres 12-1 to 12-m are held together in a bundle which is connected to a single photodetector 14.

Light sources P1 - Pn are sequentially driven with a drive circuit 16 under the control of a computer 15 in such a periodic way that the operational timing of one light source is out of phase with that of another. The outputs of the photodetector 14 are read in synchronism with the drive timing of pulse light sources P1 and Pn and supplied to an integrator 18 through an amplifier 17. The integrated outputs are subjected to analog-to-digital conversion in an A/D converter 19 and stored in the computer 15 as detection data to which are assigned addresses corresponding to the respective numbers of the pulse light sources P1 - Pn.

With the constitution described above, the light sources P1 - Pn are sequentially driven as shown in Fig. 3 to launch light beams into the head 13 through launching fibers 11-1 to 11-n. For instance, a light source Pi is driven to have light launched into the head 13 through a launching fiber 11-i. As shown in Fig. 4, the incident light is scattered and its direction becomes random as it goes deeper into the head and travels away from the incident site i. Therefore, the absorption information to be obtained from the head 13 is chiefly determined by the absorption information in the vicinity of the incident site i and that in the vicinity of the output site, and the absorption information in the remaining whole part of the head 13 merely contributes as an averaged manner. In other words, optical outputs M_{ij} and M_{im} from respective output sites j and m are expressed as follows:

$$M_{ij} = P_o S_i (\Sigma I_k) S_j$$
$$M_{im} = P_o S_i (\Sigma I_k) S_m \qquad \cdots\cdots(1)$$

where P_o: the intensity of light launched into the incident site i;

S_i: the light transmittance in the vicinity of the incident site i;

I_k: the light transmittance in the internal part of the head 13 (e.g., site k);

S_j: the light transmittance in the vicinity of

the output site j; and

S_m: the light transmittance in the vicinity of the output site m.

It is assumed in obtaining equation (1) that in the process of light travel to the output sites j and m the light transmittance in the internal part of the head 13 is averaged as expressed by ΣI_k and the same value of light transmittance is picked up from any output site.

The optical outputs M_{i1} to M_{im} from all output sites are supplied to the single photodetector 14 through associated pickup fibers 12-1 to 12-m and added together to produce:

$$M_i = \sum_{j=1}^{m} M_{ij}$$
$$= P_o S_i (\Sigma I_k)(\Sigma S_j). \qquad \cdots\cdots(2)$$

As one can see from equation (2), the light transmittance values of individual output sites are averaged by summing up outputs M_{i1} to M_{im} and as a consequence, a parameter that is proportional to the transmittance S_i at incident site i can be detected by the photodetector 14. Light from pulse light source P_i is cyclically launched into the head 13 at the incident site i, and the transmittance S_i at the incident site i that is detected with the photodetector 14 at each time of light launching is sent to the integrator 18 via the amplifier

17 to be integrated prescribed times. The integrated transmittance S_i is subjected to analog-to-digital conversion in the A/D converter 19 and stored in the computer 15 as detection data corresponding to the pulse light source P_i.

Pulse light sources other than P_i are sequentially driven and similar operations are performed to determine the light transmittance values of incident sites other than i as detection data that correspond to the respective driven pulse light sources. The detection data thus obtained are processed by predetermined procedures to determine the time-dependent change in the transmittance, that is, the light absorption at a plurality of local sites, that is, the incidence sites in the brain.

In the prior art examination apparatus shown in Fig. 5, a light launching fiber is located in one-to-one correspondence to a light pickup fiber and the light absorption on the straight line in the brain that connects these fibers is detected as the necessary information. This is not the case in the embodiment of the present invention described above, in which scattered light beams resulting from the launching of light at a selected incident site i is picked up simultaneously from all of the output sites and the outputs thus picked up are added together as mathematical processing. This offers the

advantage that even if the intensity of incident light P_0 launched at the site i is not very high, the absorption of light at the local incident site i can be detected with high sensitivity. As a further advantage, any variation that might occur in the result of detection as a consequence of slight changes in the position or direction in which the light launching fibers 11-1 to 11-n and the pickup fibers 12-1 to 12-m are attached can be prevented effectively in the apparatus of the present invention.

In the embodiment described above, scattered light beams from a plurality of output sites are sent to the single photodetector 14 where the individual outputs are added together. Alternatively, a plurality of photodetectors that correspond to the respective pickup fibers 12-1 to 12-m may be provided in such a way that the outputs of the photodetectors are added together in the computer 15.

The examination apparatus shown in Fig. 1 may be modified in such a way that a plurality of light sources that emit light beams of different wavelengths are employed and that comparison is made between the intensities of outputs that correspond to the respective wavelengths. In this way, the differences in absorption spectra inherent in such substances as oxygen and glucose in the brain are utilized to achieve high-speed

measurements of the spatial distribution and temporal change of a particular substance in the brain (cerebral cortex).

The foregoing embodiment concerns examination of a certain abnormality in the brain. It should be noted that the apparatus of the present invention may be applied for diagnostic purposes to other organs of a human or animal body, as well as ordinary objects to be measured such as a piece of flesh.

As described on the foregoing pages, the apparatus of the present invention is adapted to detect light absorption at a local site in an object of interest by performing mathematical processing on the intensities of scattered light beams picked up from a plurality of sites in the object. Therefore, this apparatus enables light absorption at a local site in the object to be detected with high sensitivity even if the intensity of incident light is not very strong. As a further advantage, the apparatus provides highly precise results of detection without being greatly influenced by a deviation in the position or direction in which a fixture such as an optical fiber is attached to the object to be measured.

CLAIMS

1. An examination apparatus for examining an object with transmission photometry, comprising:

a light output device arranged to direct a light beam into the object at an incidence site; and

light pickup means arranged to receive light transmitted through and scattered in the object at a plurality of different output sites and to operate in synchronism with the light source to combine signals from the different output sites to determine light absorption data for the incidence site.

2. An examination apparatus as claimed in claim 1, in which the light pickup means is arranged to combine the signals from the different output sites additively.

3. An examination apparatus as claimed in claim 2, in which the light pickup means includes a photodetector arranged to receive light from the output sites and to produce an output dependent on the total intensity of the light from the output sites.

4. An examination apparatus as claimed in claim 3, in which the light pickup means further comprises an integrator arranged to integrate the output of the photodetector with respect to time.

5. An examination apparatus as claimed in claim 2, in which the pickup means include:

a plurality of photodetectors for detecting light at respective output sites and producing a signal proportional to the intensity of that light; and computing means for adding signals from the plurality of photodetectors.

6. An examination apparatus as claimed in any preceding claim including a plurality of light output devices, arranged to direct light into the object cyclically at a corresponding plurality of incidence sites; and in which

the light pickup means is arranged in synchronism with the injection of light at successive incidence sites to combine the signals from the plurality of different output sites making successive determinations of light absorption data for respective incidence sites.

7. An examination apparatus substantially as described with respect to Figures 1 - 4 of the accompanying drawings.

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